REPEATER CONTROL SYSTEM THAT KEEPS YOU LEGAL

by Henry B. Ruh

WB8HEE

Ann Arbor, Michigan has a two meter repeater. Nothing unusual about that except that it has a few features not found in most systems, and one not known to exist in any other system. The ARROW (Amateur Radio Repeater Of Washtenaw) operates split site on 37-97, carrier access. The transmitter function is totally solid state digital control functions using IC chips, transistors and diodes.

Most repeaters ID when they are first activated and then every three minutes or so until the end of the QSO. The ARROW is set up to ID first, last, and every three minutes no matter what happens in between. Also, we mix our ID audio with the receiver audio so as not to interupt an in-progress QSO.

The ID comes on when the first signal turns on the transmitter from the receiver; this starts a three-minute timer. At the end of three minutes, it ID's again. If the QSO continues, the timer is refreshed by the COR until the input has been cleared. The ID'er will then time out the last three minutes since the last ID during the QSO and ID again. If a signal turns on the system during the eight-second transmitter tail after ID, the system will ID again and restart its cycle again. In this way, it is not possible for any signal to pass through the system without the repeater ID'ing first and last.

The transmission time limit is about 2:15. If a station times out (don't we all) the ID'er will give a steady tone for the last eight seconds prior to transmitter shutdown; this lets everyone know someone bought the timer and that there was not a malfunction and the repeater was not turned off. When the input is cleared, the system will turn on the transmitter again, ID again, wait eight seconds, then return to normal service. So again, the repeater ID's last. If someone picks up the system during those eight seconds, the system will ID again to start a new cycle. This also eliminates the question of when the timed out station finally quit. The system tells you when the input is clear by coming up and IDing--a nice touch if I do say.

To fulfill the other logging requirements, a continuous tape logger runs from the transmitter relay, so the logger is on whenever the transmitter is on. It is not necessary to drop and sign as with some systems. Using a slow speed transverse scanning logger, we get about six weeks of logging to a reel of 2400' of two-inch tape.

The repeater is in operation for 24 hours a day under most circumstances. The date (day, month and year), transmitter power, input and output frequencies, location, and mode of transmission are all entered on the log by the control station between 00:00 and 01:00 of each day of operation, which satisfies the other logging requirements.

From the July 14th FM Forum which was sponsored by the ARROW, the Association is buying a duplexer to move the transmitter site to the receiver location,

some 400' higher than present. Soon thereafter, touch-tone phone patch facilities will be connected, and multi-band operation is planned for the near future. From its location in Ann Arbor, the system covers an area from Jackson, Fenton, Detroit and Toledo. A Midwest FM Convention is now being planned for 1973.

Figures 1 through 7 show the portion of the control circuitry which controls the transmitter function, and can be readily duplicated by other repeaters to provide the same service. The control system was designed and largely built by Dave Beveridge, WB8JLC, who is presently residing in the Boston, Massachusetts area. The entire control system uses four plug-in boards for all functions: ID generator, touch-tone decode, and security control of access.

The ARROW is owned by the Amateur Radio Repeater of Washtenaw, Inc. Presently on the Board of Directors are: WA8VJQ, Bob Lowenberg; W8HST, Jeff Lackey; WB8FGZ, Dan Gooding; WB8HEE, Henry Ruh; K8RUR, Terry Babenko; K8HEW, John Stephenson; and WA9ODW/8, Carl Bubloz.

But now on to the meat of the project and a closer examination of how it all works.

Planning and forethought cannot be emphasized too much. Assuming you are about to put a repeater on the air, there are several things to take into consideration in addition to where to put the transmitter and receiver, and what equipment to use.

First, determine what repeater functions you want right now. Then think about all the goodies you might want to add later, like auto patch, tone access, PL, additional receivers and voting systems, multi-band operation, radio or wire control link, various automatic safety functions (ie, excessive heat or fire detector), unauthorized equipment cabinet entry emergency shut off, on-the-air tampering alert, high SWR protection (for when the wind takes your antenna away) or power failure alarm. Then build your control circuits to allow easy expansion in the future when you can afford it.

If you build a solid state control system as described here you will need a regulated source of power. The system shown here uses 5 volts, 9 volts and 24 volts, from a power supply totally separate from the transmitter supply. Five volts are used for IC's (assuming DTL or TTL); if you use RTL IC's you need 3.6 volts. A 9 volt supply runs the transistors for timing and function control, and 24 volts run the relays. Of course, there is no reason whay you cannot use 6, 12 or 110 volt relays, but the consideration is the size of the transistor used to drive the relay coil. A GE-62 transistor is used in the circuits shown since it is cheap, works quite well, and can handle 24 volts at the 48 mils needed for the relays we used.

Trouble shooting is very easy also since with logic circuits the signal is either ON or OFF. ON is usually the supply voltage and OFF is usually ground potential. So using a handy dandy VOM, VTVM or small light bulb you look for ground or plus 5 volts.

To decode each number, it is necessary to decode each of two tones, then add the correct combinations with a two gate adder, and invert again to produce each number. As in Diagram 3, an LG tone and an HG tone are added to produce a single output representative of the original number.

At this point, we have only decoded and combined the tones used for control and converted them from AC signals to DC logic states, either ON, or OFF. This completes the processing of the input signal—everything else works from the ON/OFF logic signals. The circuit at this point has determined which digit has been sent, ie, if you feed a "4" into the input, two PLL's decode the two tones, LG2 and HG1, and combine this two tone signal to a single action at the output of the adder. No other tone combination will activate this output.

To put this information to work, a series of flip flops is gated in series to provide access. This affords two advantages: (1) any combination of tones, and (2) any number of tones can be used to access the control circuitry. For convenience, a three digit access is shown in Figure 4. This could be expanded or compressed to suit your paranoia about false triggering and false call ups by kids and cranks. A random three digit access is nearly fool-proof, and with a seven-second hang-up time in which to hit the proper three digits in the proper sequence, will foil most attempts to illegally gain access even if your control telephone number is discovered. Additionally, since there is no indication to the caller when something happens, there is no way to jinx the system by pushing buttons until something does. Also,

should a wrong digit be pushed at any time, the system clears and nothing happens anyway. Additionally, a supervisory control using additional digits is incorporated to turn on and off the control system should a control station start playing games. An on-the-air tattle tale is incorporated; when access to control is finally gained, by using the proper three digits the system ID's. The actual digits used for each access and function should be kept secret. The only functions the control station need know are normal access, system on, and system off. It's probably better to leave the other functions to the people who own and work on the system, and only a few key personnel, ie, trustees, should know the supervisory access to override any one else. So, on to Diagrams 4 and 5.

Following the signal from the decoded digit outputs, each preselected digit to access is fed to the appropriate flip flop. Digit A must be first sent to gate open the first flip flop, which enables flip flop B; then digit B must be sent to open flip flop B. Then the function digits A through I can be sent to produce the desired function. Care should be taken to avoid a conflict with digit S1. This would be the third digit sent by the supervisory control station, after which S2 or S3 to turn on or off the control circuitry at gate F. This is an AND gate, and both inputs must be high to allow access to the function gates, A to I.

As you can see, it takes three digits to perform any function, and six digits for the supervisory control to perform any function. Also, once the supervisory control is used, it takes the right five digits to regain access.

The clear line is fed from a number of other function generators as seen on Diagram 5. All unused digits, those left over from access, are fed to an AND gate. Should any of these be sent during access procedure, through a series of gates, a clear signal is fed to the access flip flops, resetting them. Since we also use the same tone decoders for auto patch, if a 0 or 1 is decoded as first digit from the incoming receiver audio, it also sends a clear signal, resetting the control system. The remainder of the control circuit is rather straight forward, and the diagram is labeled as necessary. The UJT's each have a small value resistor in the B1 lead to offset temperature instability, and each function has been separated as much as possible to allow you to easily follow out any action in the system. The electrolytic capacitor in the E lead of the UJT's determines the time limits. The 25 ufd capacitor near gates P1 and P2 determines the key up length of time to turn on the air patch and turn it off again. With the 25 ufd's it takes about four seconds of tone to set the function. For safety, a longer length than the access is used to avoid false triggering, and only one tone of a touch-tone group is used for key up, and another single tone for key down of the auto patch. The patch clear timer is a safety, should the mobile forget or drop out of the system, and automatically clears the patch and hangs up the phone.

The entire control system was built on one board using 36 IC's and nine transistors. Sockets and wire wrap point to point wiring was used. The touch-tone decode portion with its seven IC's and ring detect was on another board with lots of room to spare. The ID'er and its controls are on two boards, diode matrix on one and time generators on the other. This allows

removal of any of the four major portions of circuitry without disturbing the entire system. An auxiliary ring-on, ring-off board is used to replace the control board when it is removed for service or check up.

When constructing the ID'er, it was decided that it would do many functions besides send DE WB8CSC. The same tone oscillator is used to indicate system time out, tattle on control tampering, and indicate when a control station has been using the line patch to listen to the receiver, since the control station has to renew the phone hang up timer every minute. The same digit is used for ID, IDing the system each time the line patch time is renewed.

The timers also function to keep things legal. The ID'er always has the first and last word on any transmission or series of transmissions. If the system is keyed up, the ID'er immediately keys up. Three minutes later, whether additional transmissions are made or not, it keys up and ID's again. The system is then dormant until another station keys up. The ID'er will always key up every three minutes provided there is a transmission during the three minutes--if there is none, at the end of the three minutes it ID's and shuts down. ~~The diode matrix and dah, dit and space timers are not shown here since there is a prolifery of material on this subject already.~~

Diagram 6 shows the actual transmitter control circuit used, and the various inputs and clearing signals are shown. The diagram is quite simple in operation.

The normal amount of care should be taken during construction, and double check all connections to IC's. With such a complicated array of functions in a single area, a mistake can be very hard to locate after the wiring has been completed.

A close look at Diagram 5 shows that the auto patch is used two ways. One, an off-the-air signal can access the patch with the right tone decoded into P1, and turn off the patch with the right tone at P2. In addition, a control station may use the patch in reverse; that is, call the transmitter and call up the patch through the patch on and transmitter on (Diagram 6) function and talk through the repeater and listen on the phone to the receiver similar to a remote base operation. This allows emergency traffic to have absolute priority over any incomming signal, when entered through the control system, with the control station identifying in the normal manner. Since this second function is only for emergency, a one-minute timer cuts off the incoming call unless the access renew is activated. This same function also starts the ID'er.

Also, the ID'er is started each time the control circuit is accessed from the phone line, to tattle on any possible hi-jinks by a control station.

From Diagram 6, two distinct circuits are visable. The one on top is the actual transmitter ON/OFF, and the lower is the ID dot, dash, space generator driven from the common diode matrix. The entire generator functions to turn on and off Q8 and Q7 which generate the audio tone which is fed to the transmetter and logger input through a .01 capacitor and 10K pot for level control.

This way the ID'er is mixed with the receiver audio and does not interupt any in-progress QSO.

The COR drives a flip flop by grounding the input. This starts several functions: (a) it starts the three-minute ID timer; (B) it starts the two-minute out timer; and (C) it turns on the transmitter provided the system enable is ON (C on diagram). If the enable is OFF, nothing will turn on the system. If the system is enabled (ON) the transmitter ON/OFF flip flop marked A and B on the diagram will turn on the transmitter until B turns it off or Enable D turns it off. In practice, A and B are controlled by the patch functions.

The time out timer runs a flip flop which, besides turning off the transmitter, keys a continuous tone from the ID'er until the RC of Q9 discharge dropping the actual transmitter relay. Ten ufd provided two seconde of transmitter "tail", 50 ufd provides about eight seconds of transmitter "tail". When the input has been reset by a lack of signal, it resets the timers and starts the ID'er from the time out flip flop clear signal. This turns on the transmitter again announcing that the input is now clear for the next transmission.

Any new transmission after the timeout reset starts the entire timing cycle over, starting with an ID, reset of ID and time out timers, and refreshes the transmitter on and tail timers.

NOTE TO PUBLISHERS: The diagram used for No. 6 cannot be reprinted or photocopied unless all the IC identifying letters and pin connection numbers are removed. It is suggested that your Art Department redraw the diagram with only the discrete component values and gate functions indicated. Additionally, you might want to add a brief description of logic gates and functions of AND, OR and INVERT.

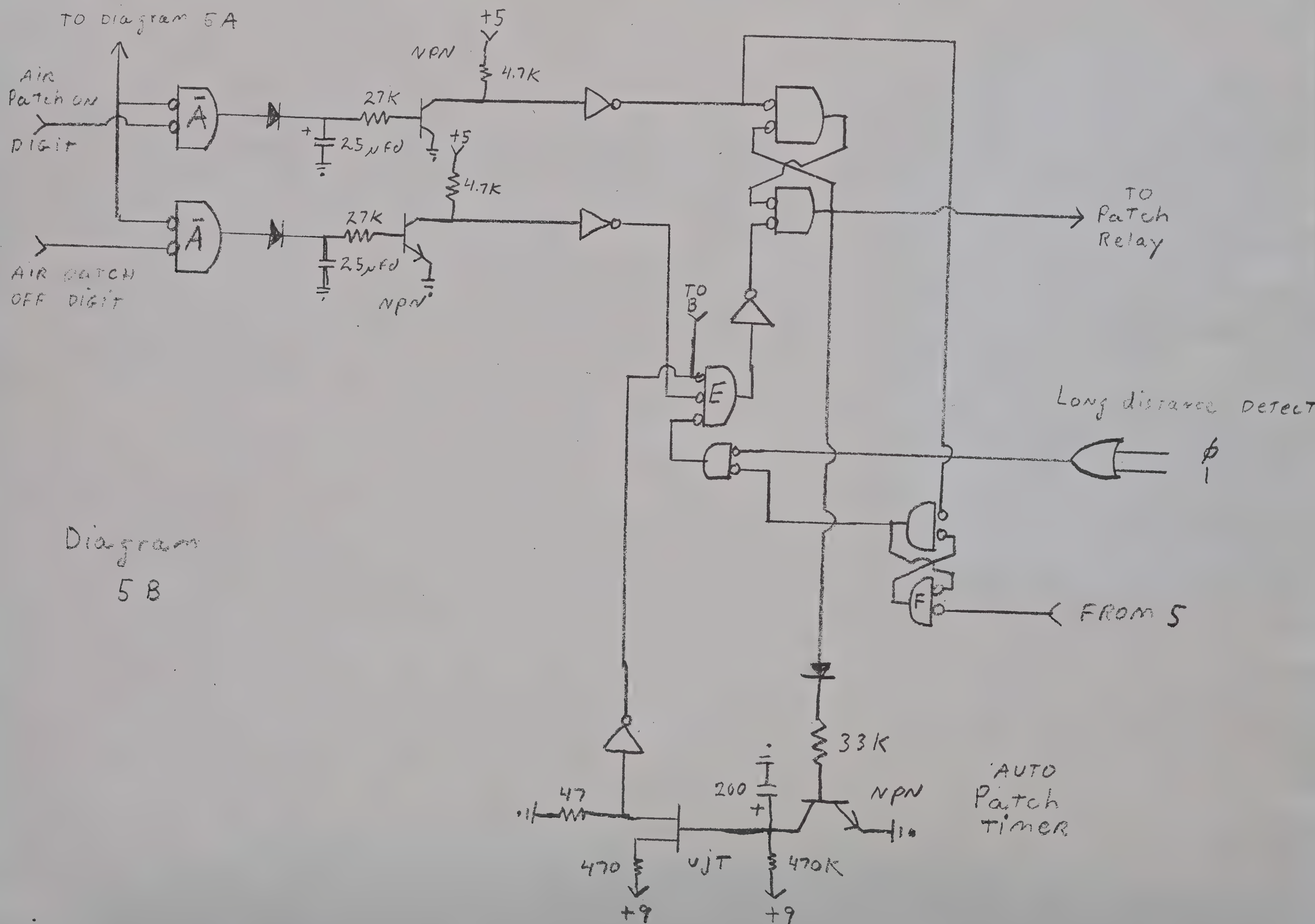
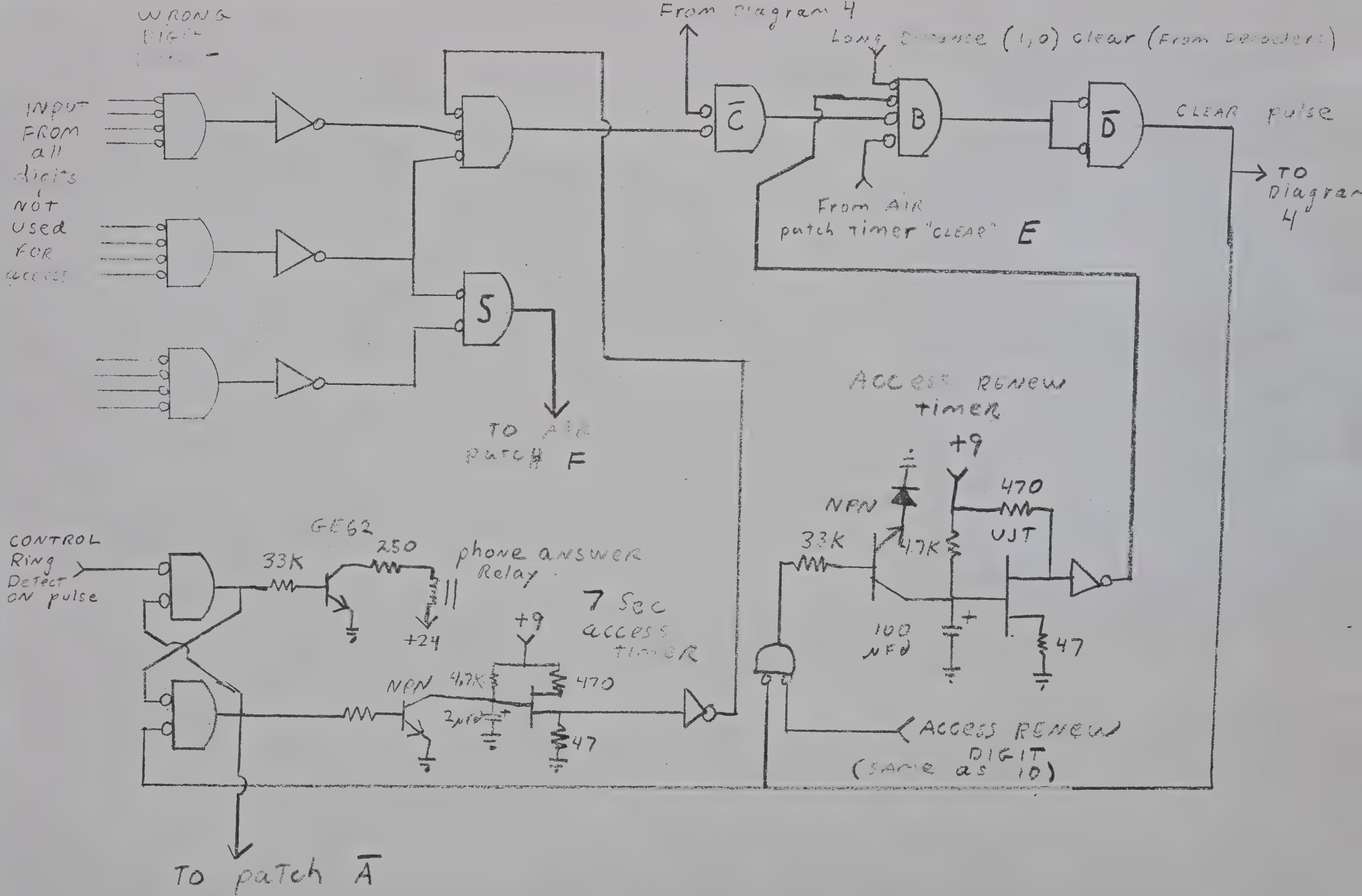

TO Diagram 5A
AIR Patch ON DIGIT
AIR PATCH OFF DIGIT
$\bar{A}$
$\bar{A}$
27K
27K
25 μfd
25 μfd
NPN
NPN
+5
+5
4.7K
4.7K
TO B
E
F
TO Patch Relay
Long distance DETECT
ϕ
1
FROM 5
47
470
+9
UJT
200
470K
+9
33K
NPN
AUTO Patch Timer

Diagram 5B



WRONG DIGIT
INPUT FROM all digits NOT used FOR access
From Diagram 4
Long Distance (1,0) clear (From Decoder)
C
B
D
CLEAR pulse
TO Diagram 4
From AIR patch timer "CLEAR" E
S
TO AIR patch F
ACCESS RENEW timer
+9
470
NPN
33K
4.7K
UJT
100 uFd
47
CONTROL Ring Detect ON pulse
GE62
33K
250
phone answer Relay
+24
7 Sec access timer
+9
NPN
4.7K
470
2ufd
47
ACCESS RENEW DIGIT (SAME as 10)
TO patch A

DIAGRAM 5 A

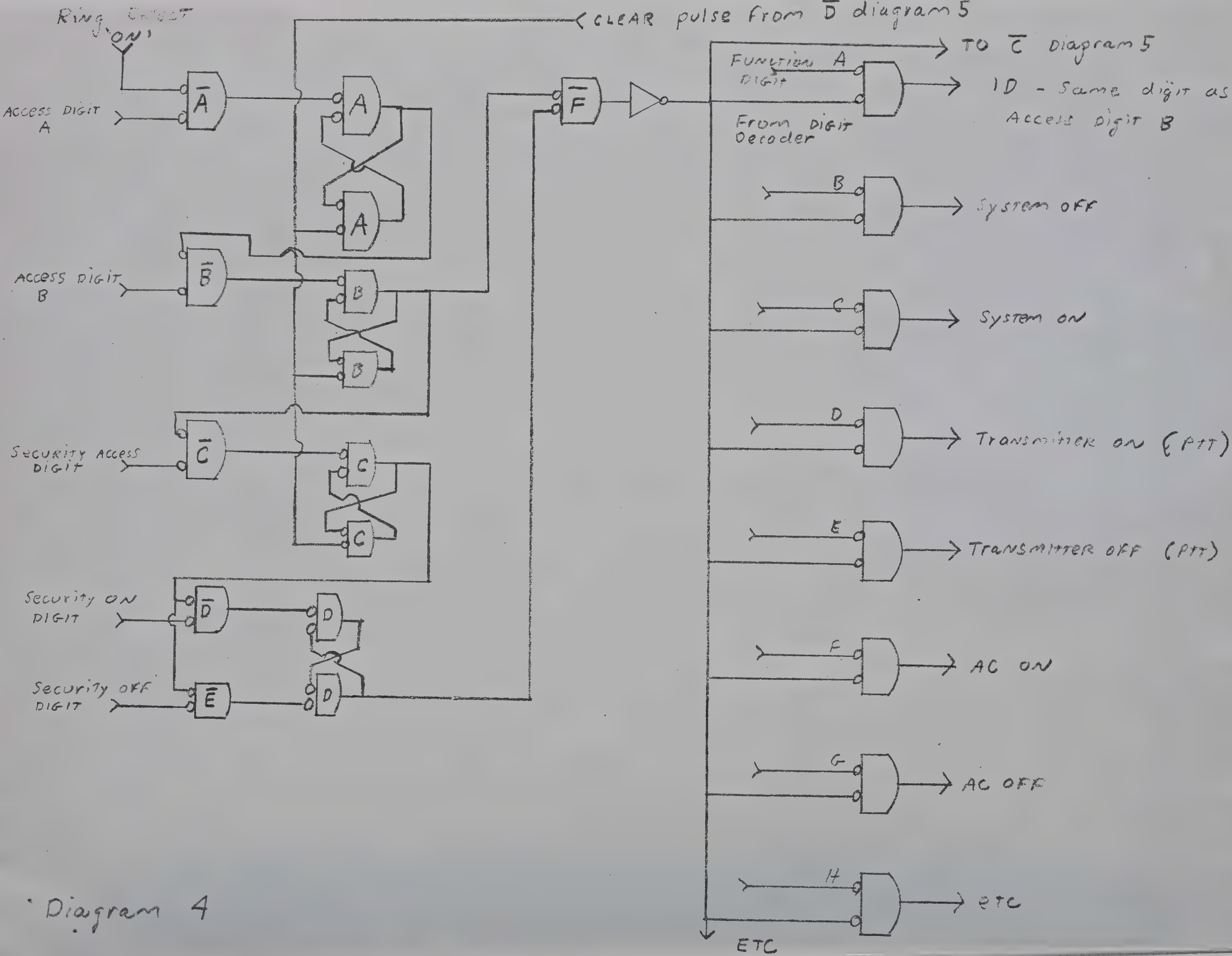
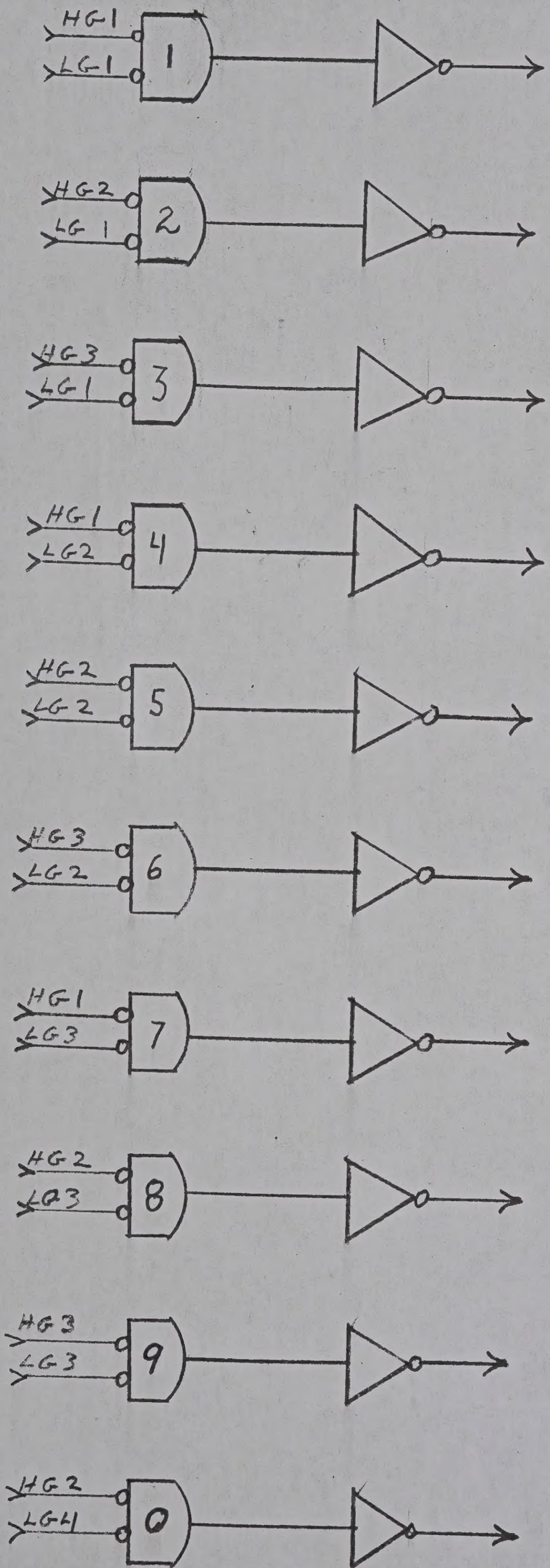

Ring 'ON'
ACCESS DIGIT A
ACCESS DIGIT B
SECURITY ACCESS DIGIT
Security ON DIGIT
Security OFF DIGIT
$\bar{A}$
A
A
$\bar{B}$
B
B
$\bar{C}$
C
C
$\bar{D}$
D
D
$\bar{E}$
$\bar{F}$
CLEAR pulse from $\bar{D}$ diagram 5
TO $\bar{C}$ Diagram 5
FUNCTION DIGIT
From DIGIT Decoder
A
1D - Same digit as Access Digit B
B
System OFF
C
System ON
D
Transmitter ON (PTT)
E
Transmitter OFF (PTT)
F
AC ON
G
AC OFF
H
etc
ETC

Diagram 4

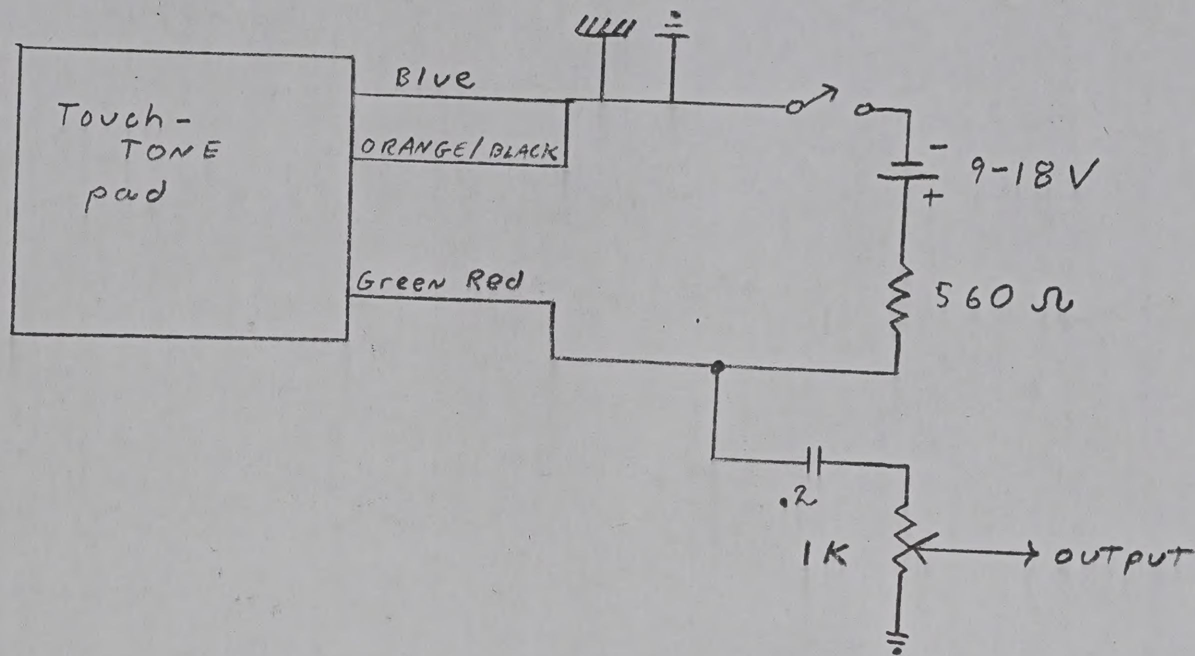
Diagram 3

INPUT IS From OUTPUT OF INVERTER OF EACH TONE DECODER as NOTED



DIGIT Logic OUPUT TO CONTROL FUNCTION CIRCUTS

NOTE: * and # can be USED BY ADDING 2 more AND Gates and INVERTERS.



	HG 1	HG 2	HG 3
LG 1	1	2	3
LG 2	4	5	6
LG 3	7	8	9
LG 4	*	0	#